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# Forest Health Protection

## Pacific Southwest Region

File 3420 Date: October 21, 2003
Route: 2470

Subject: Disease and Insect Conditions in Stand 119, Compartment 381, Almanor Ranger District, Lassen National Forest (FHP Evaluation NE03-7)

To: District Ranger, Almanor Ranger District, Lassen National Forest

At the request of Lauren Payne (Culturist, Almanor RD) Forest Health Protection (FHP) evaluated the insect and disease conditions in Stand 119 of Compartment 381 on the Almanor RD. The objective of this report is to provide input to Lauren on disease and insect activity in Stand 119 and how this activity might effect proposed vegetative management projects for Stand 119. Bill Woodruff (FHP Plant Pathologist) and Lauren examined Stand 119 together on July 25, 2003. A variety of tree diseases were present but none was causing a significant problem. In general, the health of this stand appears good.

<u>Existing Condition</u>

Stand 119 is a mixed conifer stand with Douglas fir, white fir, incense cedar, sugar pine and ponderosa pine. The basal area is 197 $ft^2$/acre and the stand density index is 444. Stand 119 has a Site Index 80 (Dunning & Reineke, Tech. Bull. 354) which equates to a low Forest Service Site Class 2. The management objective for this stand is to create a defensible fuel profile zone (DFPZ) to protect the nearby dwellings and community from wildfire. Diseases present include annosus root disease (caused by *Heterobasidion annosum*), white fir dwarf mistletoe (*Arceuthobium abietinum* f. sp. *Concoloris*), elytroderma disease (cause by *Elytroderma deformans*), incense cedar rust (*Gymnosporangium libocedri*) and branch flagging on sugar pine

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which may be white pine blister rust (*Cronartium ribicola*).

Insect and Disease Occurrences

Stand 119 is a second growth stand with many mature conifers. Evidence of annosus root disease was found in a white fir stump. Annosus conks were not found, but delaminating wood like that associated with annosus root disease was present. However, to confirm the presence of specific root decay fungi, definitive signs of the pathogen need to be found, or the pathogen needs to be isolated from host tissue. The crown of a white fir tree close to the decaying white fir stump appeared stunted. This is an indication that the tree might have annosus root disease. The base of this white fir tree had woodpecker holes, an indication that boring insects were present. Several additional white fir trees in the stand appeared stunted as well. Annosus root disease commonly occurs in white fir stands in California, and the disease is known to occur in the vicinity, so the disease is likely present in Stand 119. At this time, annosus root disease is not seriously impacting the white fir in this stand.

Two strains of *H. annosum* are known to exist in the US. The s-type (spruce type) is the strain that infects Douglas-fir, true firs and giant sequoia. The p-type (pine type) infects most pines, incense-cedar, some shrubs, and a few hardwoods. P-type has been known to occasionally infect s-type hosts, but not vice-versa. No *H. annosum* was found in ponderosa pine in Stand 119, so it is assumed that the s-type annosus is the pathogen. The effects of annosus root disease in true fir can be lessened by thinning the trees and removing competing trees and other vegetation in order to enhance tree vigor and growth.

Incidental occurrences of four other pathogens and two forest insects were found in Stand 119. Like the annosus root disease, none of these appears to be significantly affecting the stand or the individual trees within the stand. White fir dwarf mistletoe, *A. abietinum* (fs *concoloris*) was seen on a few sapling white fir trees. Elytroderma disease (cause by *E. deformans*) was seen on several ponderosa pine trees in and around Stand 119. Incense cedar rust (caused by *G. libocedri*) was found on some sapling incense cedar trees. Branch flagging (ie. dead branches with brown needles) was observed on several sugar pine trees. This may be white pine blister rust (caused by *C. ribicola*).

Management Implications

The pathogens that might impact future management in Stand 119 are *Heterobasidion annosum* and dwarf mistletoe in the white fir. At this time, both of these diseases are incidental. Furthermore, both of these diseases infect only white fir. Since white fir is a small component of Stand 119, intensification of these diseases would probably never seriously impact this stand because of the diversity of tree species present. Where possible, it is usually wise to grow a

diversity of tree species in forests. In addition to minimizing the effects of insects and diseases on a forest, a diverse forest can provide ecological, aesthetic and economic benefits.

Signs of annosus root disease were found in several locations in the stand. The only treatment for eradicating root disease from infected stands is to remove all host trees until all living remnants of the pathogen in the roots are dead. This can take up to 50 years in some cases. In situations where this treatment is not an option, the only alternative is to maintain vigorous growth by thinning trees and removing other vegetative competition from infected trees. Since *H. annosum* spores can infect healthy roots through freshly cut stump surfaces, it is recommended that freshly cut stump surfaces be treated with the fungicide Sporax® when there is a threat of infecting healthy roots. Since with true fir we cannot be sure which roots are infected with *H. annosum* and which are not, it is wise to treat fir stumps with Sporax® when the adjacent trees appear to be healthy.

As stated above, only incidental occurrences of suspected annosus root disease were observed. However, suppressed white fir infected with *H. annosum*, will eventually develop root decay. Thinning infected fir will increase tree vigor and promote root growth which can strengthen roots faster than the decay is weakening them. If infected white fir are allowed to remain stressed and overcrowded, they will develop advanced root decay from *H. annosum* and be killed by the disease or weakened and killed by the fir engraver (*Scolytus ventralis*). At some point each affected tree will die and/or blow down during high winds. Removing nearby trees which are sheltering a tree with advanced root, butt or bole decay will subject the weak tree to wind gusts which may topple it. For this reason, when thinning stands of large white fir trees known to be infected with *H. annosum,* it is wise to remove the trees with unhealthy appearing crowns. Poor crowns indicate less vigor and a higher susceptibility to root disease. Fir trees with the healthiest-appearing crowns should be retained.

Light infestations of white fir dwarf mistletoe are present in Stand 119. The observed dwarf mistletoe plants were growing on the lower branches of a sapling white fir in the northern part of the Stand 119. As stated above, this disease appears incidental at this time. The presence of dwarf mistletoe in the understory is a good indication that it may be present in the overstory. When managing multi-storied stands, it is important to be mindful of the presence of dwarf mistletoe in overstory trees which can easily spread to future crop trees in the understory. If left untreated, dwarf mistletoe will intensify and weaken the host. The diversity of tree species is again beneficial to Stand 119 since non-host trees shield uninfected fir trees from those infected with dwarf mistletoe. Dwarf mistletoe may intensify in isolated groups of white fir but the seed will rarely be disseminated beyond non-host trees. When thinning the white fir in Stand 119, it is wise to remove trees with the heaviest dwarf mistletoe infestations first.

As mentioned above, elytroderma disease, incense cedar rust, and possibly white pine blister rust are present at very low levels in Stand 119. Once again, the diversity of tree species in the stand limit the impact of these diseases, since each of these diseases is host specific. Some of the ponderosa pine plantations near Stand 119 have recently been serverely impacted by elytroderma disease because a mono-culture of pine was planted were a mixed conifer stand once was. Planting almost pure ponderosa pine (susceptible host) in a humid environment (area around Lake Almanor) that is favorable for *E. deformans* which is present adds up to a situation which favors the elytroderma disease. Pure pine should not be planted in humid areas where *E. deformans* is present. No disease was found on Douglas-fir in Stand 119. Douglas-fir might be a good species to favor in Stand 119, except for the fact that s-type annosus root disease can sometimes infect Douglas-fir.

Several sugar pine trees exhibited branch flagging which appeared to be caused by white pine blister rust. However, pronounced cancers and blister-like fruiting bodies were not present to confirm the presence of this disease. White pine blister rust is known to exist in the vicinity, so if sugar pine is planted in Stand 119, rust-resistant seedlings should be used.

Summary
Overall, Stand 119 is quite healthy. Low levels of a number of diseases are present. At this time, annosus root disease and dwarf mistletoe has the most potential for future damage to the white fir. Thinning to maintain white fir vigor will minimize the effects of annosus root disease on the white fir. Thinning to remove dwarf mistletoe infested white fir will help reduce the long-term effects of this disease. The conifer species diversity in Stand 119 plays a major role in minimizing the effects disease has on the trees.

The appendix of this report contains biological summaries for the diseases and insect discussed. A copy of Forest Service Handbook, FSH 3409.11, on annosus root disease is also included. More information on these and other forest diseases can be found in USDA Forest Service, Agricultural Handbook 521: Diseases of Pacific Coast Conifers. A copy should be available on the Almanor Ranger District. If you need further assistance, please do not hesitate to call me at 252-6680.

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# APPENDIX

## Annosus Root Disease

*Heterobasidion annosum* is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos* spp. and *Artemisia tridenta*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, *H. annosum* grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from *H. annosum* are mainly the result of windthrow resulting from root decay, and reduced root systems which predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

In general, infections will cross from roots of pine to roots of true fir; however, rarely is the fungus observed to cross from true fir to pine. At higher elevations where pine and true fir are intermixed, *H. annosum* is commonly found only on true fir and mortality rarely includes both species within an infection center.

## White Fir Dwarf Mistletoe

White fir dwarf mistletoe, *Arceuthobium abietinum* f. sp. *concolor*, is a seed-bearing plant that parasitizes only white fir. It will not survive without living host tissue, which it depends on for support, food, nutrients, and water.

Dwarf mistletoes initiate their life cycle when a seed lands on a needle or small twig of a host. The seed is coated with viscin, a sticky substance that allows it to adhere to the host tissue. During rains, the viscin becomes mucilaginous, allowing the seed to slide down to the needle base where it may lodge. The seed germinates in the winter or spring and the radicle grows along the twig until it reaches a needle base or bark irregularity. The radicle forms a holdfast and penetrates the twig

into the xylem. A type of root system then develops in the twig. In 3 to 5 years from seed deposition, most successful infections will appear as branch swellings and will bear mistletoe shoots. These shoots will not produce fruit until at least 5 years following seed deposition, the average being 8-9 years. Fruit mature in the fall and disseminate seed in September and October. The seeds are explosively discharged from the fruit through the buildup of turgor pressure. Seeds normally have an upward trajectory.

True fir dwarf mistletoe does not spread rapidly following establishment. Vertical spread in a tree averages less than 3 inches per year. Horizontal spread in a stand without overstory infection is also quite limited. Dense foliage limits spread because of the high probability of interception of the seed. Spread from infected overstory to understory may be up to about 100 feet, but it is usually less; the actual distance is dependent on slope, wind, and other factors. Trees less than 3 feet tall have a very limited chance of infection because of their small target size.

## Elytroderma Disease

The fungus Elytroderma deformans causes the most serious needle disease of ponderosa and Jeffrey pines in California. Occasional hosts include lodgepole, knobcone, Coulter, and pinyon pines. Unlike other needle diseases, Elytroderma infects twigs and branches systemically, allowing continued reinfection of a host's new needles even under adverse environmental conditions. Elytroderma impact is most severe in recreation forests, where the unsightly appearance of infected trees and occasional mortality can degrade the appearance and health of a stand.

Fungal fruiting bodies (hysterothecia) release spores from infected needles in late summer and early fall. Spores are windborne to susceptible hosts and, if environmental conditions are suitable, they germinate and infect the current year's needles. Initially, the fungus grows through the needle and into the twig without killing the needle. The following spring, infected needles die and turn a conspicuous red-brown. Infected branches take on a characteristic appearance, with current year's needles looking green and healthy while the one-year-old, infected needles are bright red-brown. Long, narrow, dull black fruiting bodies form on all surfaces of the dead needles and mature later in the summer, completing the infection cycle.Fungal mycelium within the twigs spreads into the growing tips and buds, deforming future branch growth. As a result, infected branches have a broomed appearance similar to that caused by dwarf mistletoes. However, Elytroderma brooms are distinguished by several characteristics: the red-brown color of one-year-old needles in spring and early summer; fruiting bodies scattered over the needle surface; resinous, brown necrotic lesions in the inner bark of twigs and branches infected for three years or more; and, a lack of mistletoe shoots or basal cups. Elytroderma disease kills one-year-old needles prematurely and deforms infected twigs and branches. Generally, pines are little affected if fewer than 40 percent of the twigs are infected. The disease seldom kills mature trees directly, but moderate-to-severe infection can predispose them to bark beetle attack. The disease is most severe on seedlings, saplings, and poles that are suppressed or have thin crowns. Disease outbreaks are uncommon, but once started, the disease can persist for many years, particularly in moist sites.

## Incense-cedar Rust

Incense-cedar rust (*Gymnosporangium libocedri*) is one of the most abundant rust fungi on conifers in western United States. *G. libocedri* alternates between incense-cedar and rosaceous shrubs, predominantly *Amalanchier* spp. (serviceberry). It causes only minor damage except on the leaves and fruits of serviceberry and hawthorn.

Incense-cedar rust is found throughout the range of incense-cedar. It infects trees of all ages. The fungus seldom kills branches, except small ones. Often the mycelium penetrates an older twig, resulting in a typical witches-broom. Heavily infected trees bear many brooms and may be seriously weakened, but few trees die of this disease. An infection in the main stem of incense-cedar may result in burls that cause defect in lumber.

*G. libocedri* is a heteroecious rust fungus alternating between incense-cedar and several members of the rose family. In contrast to the other major heteroecious rusts (eg. white pine blister rust and western gall rust), *G. libocedri* has its pycnial and aecial stages on rosaceous hosts. It lacks a uridial stage and the telial stage is on the conifer host. In early spring, small infected branches of incense-cedar trees appear slightly discolored. On the underside (rarely on the upperside) of green, flat, scale-like leaves, a number of small brown to brick-colored tufts or telial cushions develop. When they mature, the cushions become gelatinous during wet periods in spring and finally form conspicuous light orange masses that later dry to a thin film. The sporidial stage is blown to the rosaceous host, where small, orange, cup-shaped fruiting bodies appear on the leaves, petioles, and sometimes the fruit. These fruiting bodies produce the aeciospores, which infect incense-cedar. Moist conditions favor infection.

Witches-brooms caused by *G. libocedri* are frequently mistaken for plants of the incense-cedar mistletoe. This mistletoe, however, always hangs down in thick clusters, whereas the bushy witches-brooms cause by the rust are more or less erect.

White Pine Blister Rust

White pine blister rust (*Cronartium ribicola*) is caused by an obligate parasite that attacks 5-needle pines (eg. Sugar pine and western white pine) and several species of Ribes. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on Ribes. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to Ribes where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other Ribes throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes leaves in the fall. Teliospores germinate in place to produce spores (sporidia) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes, its spread from Ribes back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers whose closest margins are more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.

Environmental conditions are critical for successful infection and limit the disease most years. Moisture and low temperatures favor infection of both hosts, and must coincide with spore

dispersal for infection to occur. In California, these conditions occur only infrequently, usually in cool moist sites such as stream bottoms or around meadows. In so-called "wave years" when favorable conditions occur, high levels of infection can result. Wave years in California have occurred at approximately ten-year intervals in the past. As one moves from sites most favorable for rust to less favorable sites, the frequency of wave years decreases.

Fir Engraver

The fir engraver, *Scolytus ventralis*, attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after the beetles have emerged.

FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK

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CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

62 - DISEASES.

62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property.

The goal of annosus root disease management in the Region is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

2. Biology.

a. Heterobasidion annosum (Fomes annosus) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

Infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots. References that discuss the biology and disease cycle of H. annosum include Otrosina and Cobb 1989, and Smith 1993.

Heterobasidion annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of H. annosum have distinct differences in host specificity. To date, all isolates of H. annosum from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Conks produce spores which disseminate throughout the year, but H. annosum is dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of $113^{o}$ F ($45^{o}$C) and mycelium in wood is killed after exposure for one hour at $104^{o}$ F ($40^{o}$C). Temperatures just below the stump surface commonly reach or exceed the thermal inactivation level ($40^{o}$ C) of mycelium from April to September in the Southeastern United States. In eastside pine on the Lassen National Forest, lethal temperatures reach above $40^{o}$C in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine, Douglas-fir, and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that compete with and replace H. annosum. Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. Detection. The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impeding failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of H. annosum.

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of H. annosum.

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H annosum. Use the following similar symptoms for correct diagnosis:

a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.

b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the crown out. Infection of the roots causes: (1) reduced height growth, with crowns becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.

c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of H. annosum is the presence of characteristic fruiting bodies or conks. The annual to perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime.

They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of H. annosum infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify H. annosum with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of H. annosum.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if H. annosum has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers,

thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of H. annosum. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches or greater in diameter is highly recommended during chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches. These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

a. The objectives and management direction for the stand.

b. The level of annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of H. annosum and indications of infection in living trees.

c. An estimate of the cost-effectiveness of the treatment.

d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

a. Species Conversion. Because of host specificity of the 'S' and 'P' types of H. annosum, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand my be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.

b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.

c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.

d. Stump Removal. Removal of stumps and roots infected with H. annosum would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

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